Lab 5: tsh – Getting started (Week 5, out: 17.2.17)

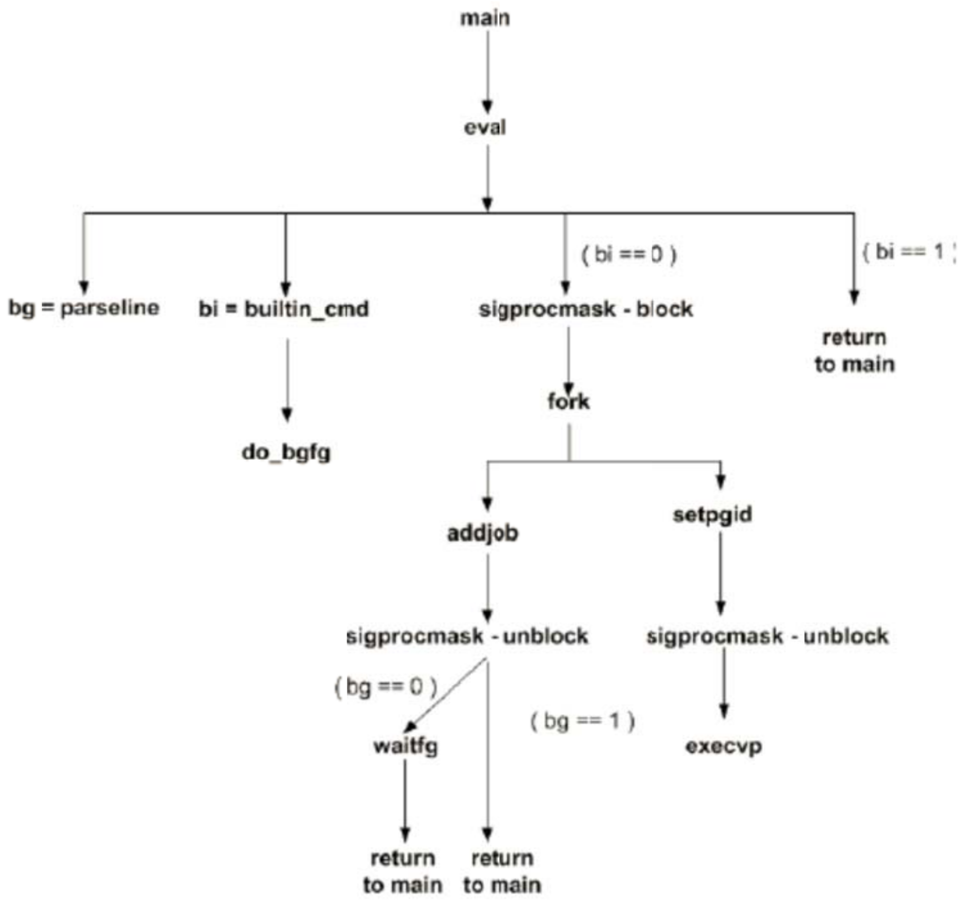
For the shell project, you are given an initial incomplete program. Some functions are already implemented or partially implemented. Others are empty and for you to complete. You may add additional functions if you wish, but the provided functions when completed should suffice.

Getting checked off:

- Show your solution for Exercise 4 of previous lab (Lab 4).
- Complete steps 1 and 2 of shell implementation and show your solution.

Note: Step 3 is provided just for reference; there is no lab checkoff for step 3. Remember, you have to implement the full specification of tsh detailed in the project handout and then turnin your solution via moodle, by March 6.

Here is a call graph of the functions provided.



Shell Implementation - Step 1

1. builtin_cmd:

   builtin_cmd should return 1 for all these "builtin" commands.

   1. quit
      Can just call exit(0) for now. Later a check should be made if there are any background jobs and exit only if there are none; otherwise, if there are any background jobs, print a message and return.

   2. jobs
      Can call the provided listjobs function to print background jobs (if any).

   3. fg and bg
      Call do_bgfg, but don't implement do_bgfg yet.

   Also until you implement code for commands that are not builtin (e.g until you fork, etc), builtin_cmd can return 1 for all commands, preventing eval from forking.

2. eval
   1. call parseline
   2. if there were **no** items on the command line return to main
   3. call builtin_cmd to check for builtin commands and return to main if builtin_cmd returns 1 (yes it was a builtin_cmd). Initially builtin_cmd can always return 1 whether the command is builtin or not. So eval need not add the code for calling fork, etc. yet.

Tests

Run tsh

1. Enter blank lines: should print the prompt again
2. quit command (should terminate the shell)
3. ctrl-d (should terminate the shell)
4. jobs (should print nothing at this point)
5. fg, bg (should print nothing at this point)

Shell Implementation - Step 2

In the previous step only (some) builtin commands were implemented and no child processes were created by the shell. Next add to the shell the following functionalities:

1. Error Checking for fg and bg (but no execution yet; just error checks)

2. Create child process to execute non-builtin commands (but running in the foreground only; no background processes, yet).
3. Wait for each child to finish (but NOT by calling waitpid)
4. Completely remove the child process; that is, *reap* the child process so that it is completely removed from the Linux process table. (The SIGCHLD signal handler will call waitpid to do this after a child finishes.)

Error checking for fg and bg

The do_bgfg function gets the array of command line arguments:

```
 void do_bgfg(char *argv[]);
```

This function will only be called if argv[0] is either "fg" or "bg", but its argument might be incorrect or missing.

Missing argument

The argv array will contain a NULL entry at the index after the last actual command line argument. So argv[1] will be NULL if the argument for "fg" or "bg" is missing. If the command is "fg" and the argment is missing, you should print this message and return.

```
fg command requires PID or %jobid argument
```

Incorrect argument type

If the argument to "fg" or "bg" is NOT missing, it is in argv[1].

The argument should either be the pid (an integer) or %jid (% followed immediately by the job id integer). E.g.,

```
  fg 1400
```

```
or
```

```
  fg %2
```

But any other kind of argument would be an error. E.g.

```
  fg a
```

```
or
```

```
  fg [2]
```

If the argument to "fg" is not a pid or %jid, then print this message and return.

```
fg: argument must be a PID or %jobid
```

Correct argument type, but pid or job id doesn't exist

If the argument to fg is an integer, it should be the pid of an existing job. But you need to check if it is in the job table.

Use the provided helper function

```
struct job_t *getjobpid(struct job_t *jobs, int pid);
```

This function returns the NULL pointer if no job exists for pid. For example, if the argument to "fg" is 12345 and there is no job with pid = 12345,

```
 p = getjobpid(jobs, pid)
```

would return NULL.

In that case do_bgfg should print this message and return:

```
(12345): No such process
```

Similarly, if the argument is of the form %jid, check if this jobs is in the job table with the function:

```
struct job_t *getjobjid(struct job_t *jobs, int jid);
```

If the argument to "fg" is %2 but there is no job with jid = 2, then print this message and return:

```
fg %2: No such job
```

Create Child Process to execute non-builtin commands

If the command was not builtin,

1. create a child process; using fork
2. child executes; use execvp
3. if execvp fails, child prints a message and exits.

   For example, if there is no program or command named "blob" and execvp fails, the child should print

   ```
   blob: Command not found
   ```

4. The shell should wait for the child by calling the waitfg function:

```
void waitfg(pid_t pid);
```

See below for how to provide a *temporary* implementation of the waitfg function. (The implementation should NOT call waitpid.)

Temporary waitfg implementation

The waitfg function should wait until the foreground process changes state (either terminates or is stopped) and then return. But the comment before *waitfg* warns that you should not use the waitpid function for this, but just simply loop until the job state changes. The only function that should call waitpid is the sigchld_handler. However, at this step jobs are not being added to the job table where the job state is to be recorded and maintained by the shell. But a *temporary* implementation of waitfg can be provided that doesn't call waitpid. Just call the pause function like this:

```
 pause();
```

This will block until a signal is received. When the foreground process changes state, the SIGCHLD signal is sent to the shell. This will cause the pause function to return. Don't try to run jobs in the background yet. This means there will be only one child process at a time. With this restriction, using the pause() function works to wait for that child. Once background jobs are allowed, the implementation of waitfg will need to be implemented as stated in the *waitfg* comment.

The sigchld_handler function

Recalling that signals are *not queued*, the sigchld_handler needs to loop calling waitpid until all children who have changed state (i.e., terminated or stopped) have been waited for. If there are additional children who have not yet changed state, the sigchld_handler should not wait for those children.

So the third parameter (options paramter) passed to waitpid needs to set the following in addition to the default of returning information when a child *terminates*:

- WNOHANG - return 0 immediately if additional children exist, but none have changed state yet
- WUNTRACED - also return pid if a child has been stopped (not just if a child has terminated)

Shell Implementation - Step 3

1. Implement sigint_handler and sigtstp_handler
2. Finish implementing sigchld_handler
3. Finish eval
4. Change implementation of waitfg
5. Finish implementing do_bgfg

6. Update the quit command

Implement sigint_handler and sigtstp_handler

These signal handlers should forward the signal to the foreground process job if there is one; else do nothing.

1. Use the fgpid function to get the pid of the foreground job. This function return 0 if there is currently no foreground job.
2. If there is a foreground job, use the kill system call to send the signal to the process group for the foreground job.

Note 1: The group id of the foreground job is the pid stored in the job table. Why?

Note 2: How do you send the signal to all processes in the foreground job process group?

Finish implementing sigchld_handler

If waitpid returns the pid of a child,

1. Check if it terminated normally. If so delete it from the job table. This will change all fields of the entry for the job. In particular, it changes the state entry to be UNDEF.
2. Otherwise, check if the process was terminated by a signal. If so, delete the job from the job table and print a message including the signal number that caused termination. (See the tests or run the reference shell to see the exact format and content of the message.)
3. Otherwise, check if the process was stopped. In this case, print a message (see the tests for the exact format and content) and change the state to ST, but don't delete the job.

Finish eval

1. Declare a signal set (type sigset_t) variable and initialize it to be empty (sigemptyset function)
2. Add the SIGCHLD signal to the signal set
3. If the command is not builtin, block SIGCHLD before forking a child (sigprocmask function). Why?
4. Child should create a new process group with itself as the group leader (setpgrp function) before calling execvp.
5. Parent should add the child to the job list and then unblock the SIGCHLD signal. Why?

Change implementation of waitfg

1. Get a pointer to the entry in the job table for the pid passed to waitfg.

2. Loop while the state of this entry is FG. Call sleep to sleep for 1 second between checks.

   When the state is no longer FG, return.

Finish implementing do_bgfg

1. Get the entry for the job from the job table
2. If the state is ST and the command is bg, change the state to BG and send SIGCONT signal to the process group. How?
3. If the state is ST and the command is fg, change the state to FG, send SIGCONT signal to the process group (how?) and wait (by calling waitfg).
4. If the state is BG and the command is fg, change the state to FG and wait (by calling waitfg)
5. Print appropriate messages (see the expected output from tests for the exact content of messages).

Update the quit command

Check if there are stopped jobs (how?). If so print a message, but don't exit. Just return 1.

Note:
The tsh.c program already has a nifty way of turning on/off print statements, which is useful for debugging. For example, if you wanted to print a message for debugging purposes every time the sigchld_handler executes, include this code in sigchld_handler:

```
if (verbose) {
      printf("... your message  ...\n");
}
```

Then if you want debugging messages like this printed, start the shell with the -v option:

```
tsh -v
```

This option will set the value of verbose to be 1. Otherwise, without the -v option, the value of verbose is 0. The global int variable verbose is already declared in the tsh.c file (outside any function) and so it can be used as above from any function in the tsh.c file.